Determination of steel fibre orientation in self-compacting concrete using X-ray computed tomography

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Abstract

One of the factors, which determine the mechanical properties of the fibre reinforced concrete, is the spatial distribution of fibres. Distribution of fibres in the concrete structure is influenced by the casting conditions. Therefore, determination of the spatial fibre distribution is necessary for evaluation of dependences between the fibre spatial orientation and the rheological properties.
The objective of this work was to determine the spatial distribution of steel fibres in self-compacting concrete. Three mixtures with different workability properties were selected: low, moderate and high dynamic viscosity mixtures. For estimation of the spatial orientation of fibres in self-compacting concrete post processing method of X-ray computed tomography data is proposed. The developed algorithm detects and extracts fibres from the 3D data and determines the position and orientation of each fibre. The proposed approach enables the determination of the spatial distribution of fibres in self-compacting concrete and reveals the dependencies between the rheological properties and the fibre spatial orientation.
The obtained results show how the rheological properties of self-compacting concrete affect the steel fibre orientation and distribution in different sections of samples.

1. Introduction

Various forms of reinforcement are used to improve the behaviour of loaded concrete [1]. For different structural applications, different fibre orientation characteristics are needed [1]. The alignment of the fibres is preferable for the structures, which will be loaded in one direction, while random orientation is desirable for structures that will be loaded from two or more directions. Fibre orientation is affected by concrete mixture design, casting and flow parameters [2–4], rheological properties [5], etc.

2. Materials and samples

The following amounts of aggregates have been used to produce the samples: fine aggregates of fraction 0/2 and 0/4, coarse aggregate – gravel of fraction 4/16. For sample production the synthetic zeolitic waste material from oil refinery process and Portland cement CEM II/A-LL 42.5R as the main binding material were used. For reinforcement standard hooked end steel fibres with l=50 mm length and d=1 mm diameter were used.
Three different self-compacting fibre reinforced concrete (SCFRC) 1200×150×150 mm beams with flow induced fibre orientation were casted for this study.

3. X-ray computed tomography and post processing

In order to determine the spatial distribution of steel fibres in self-compacting concrete the investigations of concrete samples were carried out using 50-450 kV macro focus X-ray tube at 450 kV and 1500 mA. Focal spot of the used X-ray source was 0.4 mm.
For the fibre extraction from the tomographic data, the Avizo software was used. For the fibre detection, the correlation between the image and the cylinder template was computed, because the fibres used had cylindrical form. Cylinder template parameters were selected according to real fibre parameters used in the samples. Then each fibre was analysed and its mass centre Cartesian coordinates, the length of the fibre, azimuthal and polar angles expressed in spherical coordinate system were determined.

4. Results and discussion

The presented results (figure 1) show different behaviour of distribution and orientation pattern. Samples produced from mix No. IF-1 (low dynamic viscosity) show the best orientation ratio in X direction while steel fibre distribution is unstable in different distances from the casting point. For Mixtures No. IF-2 (moderate dynamic viscosity) and No. IF-3 (high dynamic viscosity) fibre distribution is more stable along the flow length.

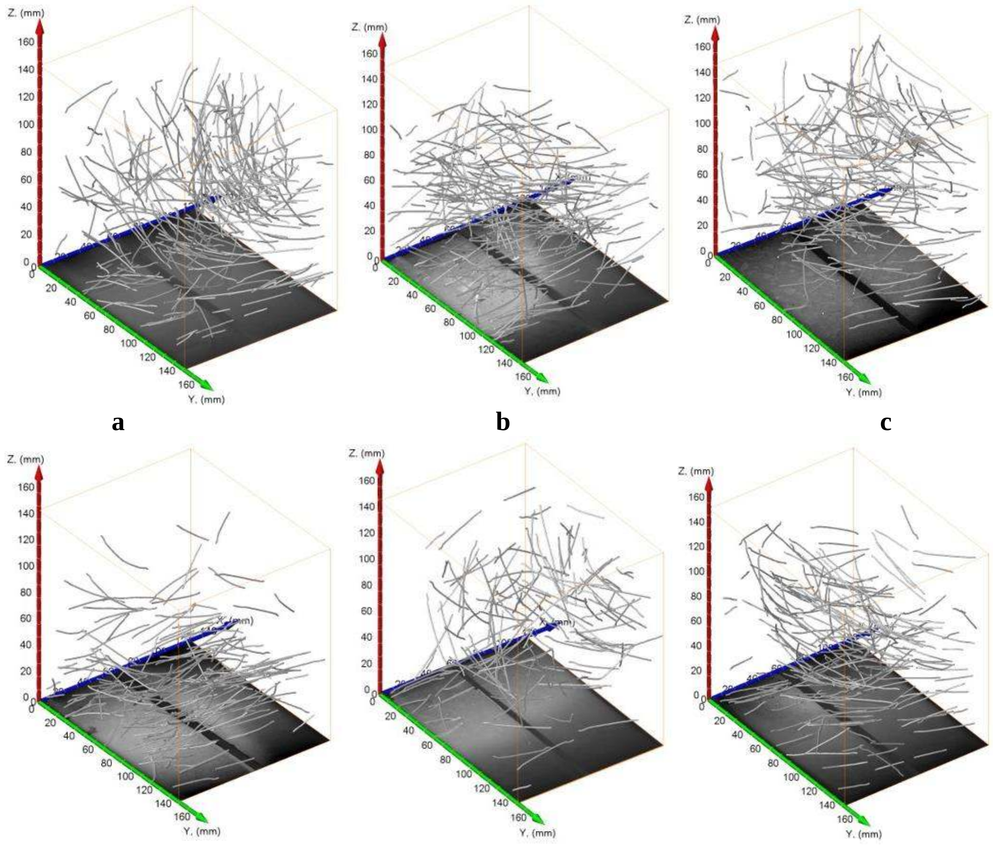

Figure 1. Distribution of fibres in different viscosity samples: a - mix code IF-1 (low dynamic viscosity, front of the formwork), b – IF-2 (moderate dynamic viscosity, front of the formwork), c– IF-3 (high dynamic viscosity, front of the formwork), d - mix code IF-1 (low dynamic viscosity, end of the formwork), e – IF-2 (moderate dynamic viscosity, end of the formwork), f – IF-3 (high dynamic viscosity, end of the formwork).

5. Conclusions

Computed x-ray tomography was used to investigate the parameters of steel fibre orientation and distribution in self-compacting concrete samples. CT provides information about each individual fibre position and orientation inside each sample. Self-compacting concrete has many advantages, but also there is a risk of fibres segregation or orientation in unsuitable direction and X-ray CT with the proposed post processing method is a perfect tool for investigation of the fibres distribution in self-compacting fibre reinforced concrete.

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